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Basic Study for Tissue Characterization of Carotid Artery Plaque using Ultrasonic Velocity-Change Imaging

超音波速度変化イメージング法の血管プラークの性状診断への応用に関する基礎研究

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1. Introduction

The detachment of blood vessel plaque is serious problem because it leads to the brain infarction and the heart infarction. If the stenotic lesion is early or middle phase, the plaque is may become stable by using drug administration or lipid control. Thus, a method is required to diagnose early stage of lipid-rich plaques that are likely to cause acute coronary obstruction.

We already proposed the ultrasonic velocity -change imaging method[1,2] to diagnose fatty liver by using the fact that the temperature dependence of ultrasonic velocity-change is quite different in water and in fat. In this study, we aimed at applying the ultrasonic velocity-change imaging method to diagnosis of tissue characterization of carotid artery plaque. Ultrasonic velocity-change images of lipid-rich area in the blood vessel phantom are constructed.

2. Ultrasonic Velocity-Change Imaging Method

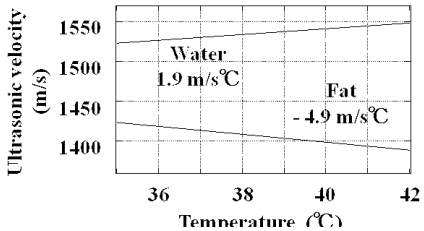


Fig.1 Ultrasonic velocity as a function of temperature

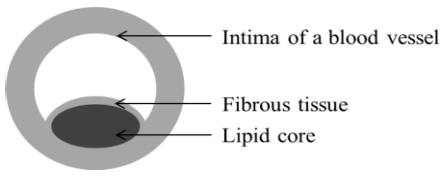
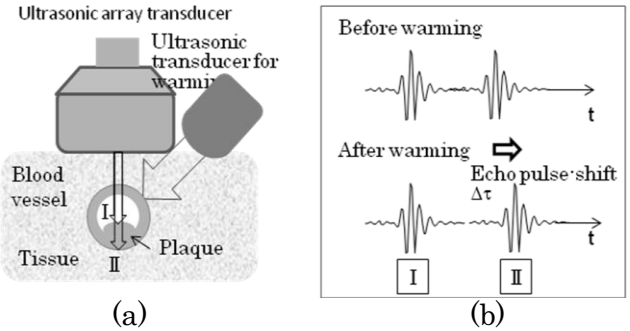


Fig.2 llustration of unstable plaque

The temperature dependence of ultrasonic velocity-change depends on the medium. The temperature change rate of the ultrasonic velocity in water is +1.9 m/s degree and that in fat is -4.9 m/s degree as shown in Fig.1. Fig.2 shows the illustration of blood vessel with plaque. The plaque including the lipid core is thought to be easily detached. As the temperature increases, the ultrasonic velocity increases in the blood and the wall of the blood vessel with high percentage of water content and decreases in the lipid core. It is thought that temperature dependence of ultrasonic velocity change is useful for identification of the fat distribution in the living body.

The ultrasonic pulses emitted from the linear array transducer are reflected from the boundaries of different acoustic impedance of the medium. When the temperature of the medium is increased by ultrasonic irradiation, the echo pulses reflected at the boundaries shift owing to ultrasonic velocity change based on the temperature rise.

Fig. 3 shows the ultrasonic pulses reflected at the boundary I and the boundary II of the vessel plaque. If the plaque includes the lipid core, the echo pulse from the boundary II is thought to be delayed by $\Delta\tau$. The ultrasonic velocity-change Δv is determined from the shift $\Delta\tau$ of echo pulse. The ultrasonic velocity-change image is constructed from $\Delta\tau$ of echo signal correspond to every acoustic scan lines.



(a) (b)

Fig.3 Principle of ultrasonic velocity-change imaging method for characterization of blood vessel plaque

3. Experiment System

Figure 4 shows the experimental set-up to get ultrasonic velocity-change images of the blood vessel phantom including the model plaque. The ultrasonic transducer for warming of the phantom is placed near by the ultrasonic array transducer.

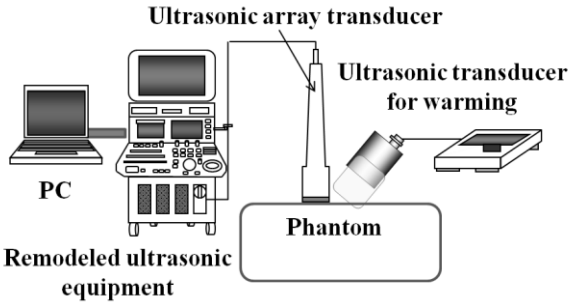


Fig.4 Experimental system of ultrasonic velocity -change imaging of blood vessel phantom

4. Experiments

The mimic blood vessel phantom was made of the agar including the graphite powder. A small piece of fat was inserted into the mimic blood vessel as shown in Fig.5. Water was streamed in the vessel instead of blood by a tube pump. After heating for 60 s (temperature rise: 1~2 degree), echo pulse waveforms were detected by the linear ultrasonic array transducer in temperature relaxation process. The ultrasonic velocity change was determined from each echo pulse waveform at different temperature.

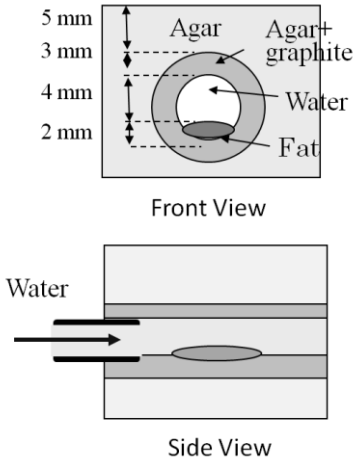


Fig.5 Structure of blood vessel phantom including the model plaque

5. Results

Figure 6 (a) and (c) show the normal B-mode images of the front view and the side view of the phantom, respectively. In Figs.6 (a) and (c), the phantom structure was observed, but the lipid-rich area was not identified. Figures 6 (b) and (d) shows the ultrasonic velocity-change images of the phantom. The ultrasonic velocity change rate was shown by the gray scale. The dark areas which indicate the minus ultrasonic velocity change rate correspond to fat distribution in the phantom.

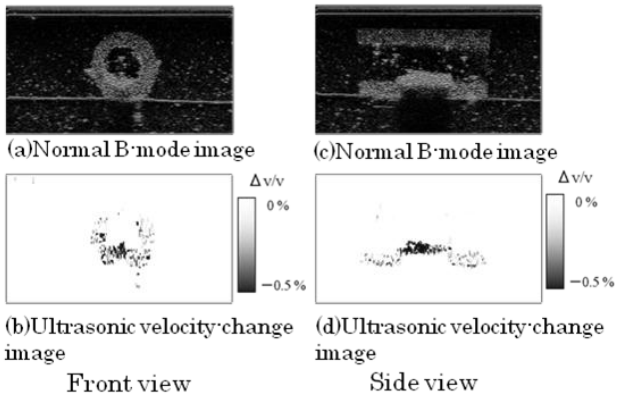


Fig.6 Ultrasonic images of blood vessel phantom including the fat area as a mimic lipid plaque

6. Conclusion

Lipid-rich areas in the blood vessel phantom were clearly displayed by using ultrasonic velocity-change imaging method. The ultrasonic velocity-change imaging method has the possibility of application to characterization of carotid artery plaque.

Acknowledgment

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References

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